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Spacecraft Utensil/Hand Cleansing Fixture

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Spacecraft Utensil/Hand Cleansing Fixture

October 1978

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FOREWORD

This document presents the results of work performed by the Martin Marietta Corporation's Denver Division for the National Aeronautics and Space Administration, Lyndon B. Johnson Center. This final report for the development of a prototype unit was prepared as fulfillment of Contract NAS9-15012, "Spacecraft Utensil/Hand Cleansing Fixture." The NASA Technical Manager was Mr. John B. Westover, Payloads Systems Support Branch.

ABSTRACT

The Spacecraft Utensil/Hand Cleansing Fixture provides a means for a crewman to perform, in zero-gravity, laboratory utensil/tool cleansing and personal hygiene functions such as handwashing, shaving, body wash and teeth brushing. A prototype unit was developed incorporating design improvements resulting from breadboard tests in a one-gravity and zero-gravity environment. The prototype unit demonstrated and capability of performing the different cleansing functions and provides the criteria for a flight unit development program.

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ABBREVIATIONS

amp	ampere
AUTO	Automatic
^oC	Degree Celsius
cc	cubic centimeter
CFM	Cubic Feet Per Minute
cm	Centimeter
CMS	Cubic Meter Per Second
Dia	Diameter
^oF	Degree Fahrenheit
ft	foot
FTM	Flow Timing Module
FPS	Feet Per Second
gal	gallon
G	Gravity
gal	gallon
gpm	gallon per minute
Hz	Hertz
ID	Inside Diameter
in	inch
JSC	Johnson Space Center
^oK	Degree Kelvin
lbs	pounds
LED	Light-Emitting Diode
LGS	Liquid-Gas Separator
m	meter
min	Minute
ml	milliliter

ABBREVIATIONS (CONT.)

n	newton
NASA	National Aeronautics and Space Administration
NBF	Neutral Buoyancy Facility
N/m^2	Newton per Squared Meter
OD	Outside Diameter
oz	ounce
PBS	Phosphate Buffered Saline
PCM	Pump Control Module
psi	pound per square inch
psig	pounds per square inch, gage
QD	quick disconnect
RLSE	Regenerative Life Support Experiment
sec	second
SMD	Spacelab Mission Development (Test)
sq	square
SUHCF	Spacecraft Utensil/Hand Cleansing Fixture
TSA	Trypticase Soy Agar
VAC	Volts-Alternate Current
VDC	Volts - Direct Current
VTS	Vertical Test Facility
vs	versus

1.0 Program Summary

1.1 Description of Tasks

The following paragraphs provide a general summary of each individual task effort that was included in the "Spacecraft Utensil/Hand Cleansing Fixture" contract.

1.1.1 Task One - RLSE Requirements Definition

This task established the requirements, both performance and design, for a cleansing fixture. Included was the design restraints to assure compatibility of the designed cleansing fixture with the zero gravity whole body shower segment of the RLSE program. Subsystems were identified along with system interfaces. Also, the allocation of performance budgets was established.

1.1.2 Task Two - Preprototype Design and Fabrication

The objective of this task was to design a preprototype hardware that could be utilized to evaluate the cleansing fixture in a series of tests consisting of one-gravity laboratory and KC-135 aircraft simulating zero-gravity. System schematics were prepared which were compatible with the program criteria. After the NASA approval of the preliminary design, detail design for the electrical and mechanical systems were established. Since the KC-135 zero-gravity tests imposed the greatest stress on the structure, the design was based on KC-135 flight requirements which encompassed the following design parameters:

- o Structural width to meet cargo tie-down requirements
- o Electrical power
- o Gas supply system
- o Ventilation system
- o Structural stress
- o Mounting holes
- o Handling provisions
- o Design and fabrication requirements

The detail design drawings were prepared to Martin Marietta's procedures and utilized MIL-D-1000, Form 3, Category A, as a design guide. Special breadboard equipment was utilized for the one-g laboratory tests involving chemical fluid dumps and testing the effectiveness of charcoal. These were standard laboratory test equipment and the feasibility hardware utilized in contract NAS9-14671.

The fabrication was in accordance with the design and was accomplished in the engineering model shop.

1.1.3 Task three - Preprototype Testing

The objective of this task was to test the preprototype hardware to provide performance and functional data that could be utilized to design a prototype cleansing fixture. Quantitative data was collected in order to assess the cleansing fixture's impact on spacecraft system. One-g laboratory tests and KC-135 tests were conducted.

A test plan was prepared to describe the proposed plan for the test of the breadboard systems. This plan was prepared in accordance with DRD TM-350T and contained separate procedures for each type of test. After receiving approval from the NASA Technical Manager, the test support hardware was assembled with the preprototype design structure and checked for operability. The tests conducted were 1-G laboratory tests, microbial burden and disinfection studies, SMD-III test support, and 0-G KC-135 testing.

1.1.4 Task Four - Preliminary System Specification

The purpose of the preliminary system specification was to provide a set of technical requirements and features of the total system so that the cleansing fixture could be described in detail. This included system requirements, interfaces, operational aspects and overall design.

1.1.5 Task Five - Prototype Design

The prototype design evolved from two major areas of criteria. First, the design must meet the functional and performance requirements that are established. Second, the final hardware arrangement and configuration resulted from results obtained during preprototype testing. Problem areas were analyzed and correction measures were incorporated into the prototype design. The detail design drawings were prepared per Martin Marietta's procedures and utilized MIL-D-1000, Form 3, Category A, as a design guide.

1.1.6 Task Six - Prototype Fabrication

The prototype was fabricated per the drawings created in task-5 by the technicians in the engineering model shop. This included the fabrication of subassemblies and their installation along with off-the-shelf hardware into a standard narrow width spacelab rack that makes up the cleansing fixture final assembly.

1.1.7 Task Seven - Prototype tests

The tests were divided into four major groups. These test areas were the subsystem checkout tests, task performance capability test, man-machine interfacing, and maintainability testing. A descriptive summary for each area will be discussed separately.

1.1.7.1 Subsystem Checkout Tests

Prior to performing task performance tests all subsystems were tested for designed performance individually and as a total system. The subsystems were the water distribution, liquid soap distribution, air processing, waste water collection, and the electrical control system.

1.1.7.2 Task Performance Capability Tests

The functional tasks that can be performed are washing hands, washing utensils, shaving, brushing teeth, whole-body sponge bath, oral hygiene, and washing of hair. The majority of the testing evolved around the washing of hands for which tank sizing and usage rates are based upon. These rates are from the SMD-III test from which the following data was extracted:

- 4 occupant/users for 30 day mission
- 25 liters/wk water usage
- 2 cc soap per usage

1.1.7.3 Man-Machine Interfacing Test

Test subjects that met the requirements of being a 5 percentile female and a 95 percentile male used the washing fixture, along with several other test subjects, and commented on the following:

- Reach the controls
- Ease of operation
- Comfort level

The subjects washed their hands per the operating procedures both with and without the suction cup shoe restraint system.

1.1.7.4 Maintainability Test

Scheduled maintenance was performed during the cyclic test. This included filling potable water tank, soap tank (if required) and draining the waste water tank. Unscheduled maintenance during this same period was documented as to type of failure, ease of component access and replacement time.

1.1.8 Task Eight - Delivery of Prototype

The prototype cleansing fixture and related equipment was packaged in a manner for maximum protection and shipped to NASA-JSC per Martin Marietta operations directive.

1.1.9 Task Nine - RLSE Coordination

Communication between Martin Marietta, Hamilton Standard and NASA-JSC personnel involved in the RLSE program has been maintained throughout the cleansing fixture development contract. Items like physical size, configuration, interfaces, schematics and operating procedures were kept up-to-date.

1.2 Test Result Summary

Tests were performed on both the preprototype and prototype cleansing fixture. The following is a summary of those tests.

1.2.1 Preprototype Test Results

Earlier in the contract a preprototype unit was fabricated and tested with the results analyzed and refinements incorporated into the prototype unit. The areas of testing included the following:

1.2.1.1 Chemical Waste Disposal

Initial tests showed this requirement to be potentially dangerous and unreliable. Too many unknown exist and a combination of certain chemicals can create dangerous reactions. The charcoal filter becomes excessively large and would require frequent inflight maintenance. A more feasible technique would be to store waste chemicals in their individual containers into a main storage box that incorporates safeguards such as recirculating air through a built-in charcoal filter to absorb possible chemical leaks.

1.2.1.2 Microbial Burden

Micro-organism counts within the enclosure were performed prior to any washings, mid-day, and at the end of the day which corresponds to approximately 70 washings. The increase in micro-organisms was 460 percent at mid-day and 768 percent at end of the day. Two interesting events were noted, first the organisms die off if left standing for a few days, and second, soap tends to kill the micro-organisms. A conclusion from the test was that daily disinfecting would adequately control the micro-organism count and that a disinfectant wipe could be used to disinfect as well as clean the washing fixture.

1.2.1.3 Neutral Buoyancy Test

These tests were performed primarily to establish comfort ranges for man-machine interfacing data.

1.2.1.4 SMD III Test

These tests, performed at Houston, simulated actual usage requirements for 7 days and resulted in numerous operation and configuration refinements. Some of the improvements include the following:

- Awkward foot switches replaced with arm buttons.
- Foot restraint removed (suction cup shoes to be used for zero-g environment).
- Hand access holes revised.
- Protrusions into enclosure minimized.
- Soap dispensing system revised.
- Stowage for towels, razor, shaving cream, etc. provided.

1.2.1.5 Zero-Gravity KC-135 Tests

These tests showed that the washing functions (hand washings, oral hygiene, shaving, utensil cleansing) could be accomplished in a zero-gravity environment. It was noted that all subsystems and components worked properly.

For more detailed information, see Martin Marietta Test Report, "Spacecraft/Utensil Hand Cleansing Fixture Breadboard Test Report," MCR-77-433, Contract NAS9-15012.

1.2.2 Prototype Test Results

The testing of the prototype Hand Cleansing Fixture was completed on August 4, 1978. The test was conducted in accordance with the Prototype Test Plan, MCR 78-580, DRD Number TM-350T.

The prototype hand/cleansing fixture was tested for functional and performance capabilities. Results indicated that the system does adequately perform the tasks imposed upon it. The tests were divided into four major groups. These are the subsystem checkout tests, task performance capability test, man-machine interfacing test, and maintainability testing. The following is a summary of the test results:

1.2.2.1 Subsystem Checkout Tests

Prior to performing the task performance tests, all subsystems were tested for designed performance individually and as a total system. The subsystems included water distribution, liquid soap distribution, air processing, waste water collection and the electrical control system.

1.2.2.1.1 Water Distribution Subsystem

The results of the test revealed the following:

- $2.8\text{X}10^{-2}\text{m}^3$ (7.4 gallons) of potable water could be stored and dispensed at $3.79\text{X}10^5$-$1.38\text{X}10^5\text{N/m}^2$ (55 to 20 psig).
- The system is water tight, no leaks.
- A variable position nozzle has a spray pattern from a straightstream to a full cone.
- Water droplets do not escape from the washing enclosure.
- Hot water temperature can be maintained between 313.7-319.2°K (105-115°F).

1.2.2.1.2 Soap Distribution Subsystem

The results of the test revealed the following:

- $3.3\text{X}10^{-3}\text{m}^3$ (0.8) gallons of liquid soap could be stored and dispensed at $3.45\text{X}10^5$ N/m^2 (50 to 20 psig).
- The system has no leaks.
- Drying of soap at the nozzle port does not affect operation.
- Internal pressure overcomes the dry film.
- 0.5CC (.03-IN^3) of liquid soap is dispensed per activation (amount is adjustable).

1.2.2.1.3 Air Processing Subsystem

The results of the test revealed the following:

- The blower draws 0.7 amps current.
- At 27 VDC the flow rate is $1.41\text{X}10^{-2}\text{m}^3$/sec (30 CFM).
- Air injection flow is 5 percent of main flow as determined by areas.

1.2.2.1.4 Waste Water Collection Subsystem

The results of the test revealed the following:

- $2.8X10^{-2}m^3$ (7.4 gallons) of waste water can be stored at $3.79X10^5N/m^2$ (55 psig).
- The system is water tight, no leaks.
- Pump is capable of transferring waste water at $3.79X10^5N/m^2$ (55 psig).
- Pump operation time of 5 seconds is satisfactory for low and high back pressure.

1.2.2.1.5 Electrical control Subsystem

The results of the test revealed the following:

- Water pump timer is set at 5 seconds (runs 5 seconds after sensor activation).
- Blower timer is set at 20 seconds (blower starts when water switch is activated and continues to run for 20 seconds after water is shut off).
- Liquid level sensor is of the water conductance type and worked consistently.
- Component electrical current demand -

Indicator Lights	0.2 amps (DC)
Blower	0.7 amps (DC)
Water Pump	2.1 amps (DC)
Water Solenoid	0.3 amps.(DC)
Soap Solenoid	2.9 amps (DC)
Electrical Heater	1.25 amps (AC)

1.2.2.2 Task Performance Capability Test

The functional tasks performed were washing hands, washing a utensil, shaving and brushing teeth. Washing of hair and the whole-body sponge bath were tasks that could be accomplished by transferring water from the fixture to a wash cloth to the users body. This test was performed to the extent that water was applied to a wash cloth and wringed out within the washing enclosure.

1.2.2.2.1 Washing Hands

The results of the test revealed the following for 614 separate hand washings:

- Water supply is sufficient for an average of 154 hand washings per $0.026m^3$ (7 gallons) of potable water. At the rate of 5 hand washings per day per 4 crewman, this amounts to 7.7 days of usage prior to required servicing (refilling potable water tank).

- The $0.003m^3$ (0.8 gallons) of liquid soap stored is sufficient for a 30 day mission without refilling. After 614 uses, a total quantity of $1.14X10^{-3}$ (0.3 gallons) of soap were used.

- 40 different test subjects had no difficulty in interfacing with the fixture.

- The unit worked satisfactory in both manual and automatic modes.

1.2.2.2.2 Washing Utensil

The results of the test revealed the following:

- Objects up to 0.15m (6 inches) in length were easily inserted into the washing fixture.
- Good visibility.
- Rinsing was fast and efficient.

1.2.2.2.3 Shaving

The results of the test revealed the following:

- Mirror was required to perform the function.
- The task was easily accomplished.
- The shaver was quickly cleaned by the straight stream spray pattern.

1.2.2.2.4 Brushing Teeth

The results of the test revealed the following:

- Rinsing of the tooth brush was fast and efficient.
- Discharging of the excess paste/saliva from the users mouth into the fixture was inefficient.
- Good visibility.

1.2.2.3 Man-Machine Intefacing Tests

A total of 40 different test subjects were utilized in accomplishing 614 handwashings. These personnel included both male and female subjects. Two of the test subjects, one approximately 95 percentile male and the other approximately a 5 percentile female performed a series of hand washing cycles in both a one-gravity and simulated zero-gravity body position. The suction cup restraint shoes were used for the male subject in the zero-gravity position. The results of the testing revealed the following:

- All male and female test subjects could comfortably perform the washing task in both 1-G and 0-G positions.
- All male and female test subjects could activate the controls and read the indicators.
- Washing operation was easily observed by all test subjects.
- Room light was sufficient to illuminate the washing enclosure and perform tasks within the enclosure.
- The suction cup shoes add approximately 0.0254m (1-inch) the users height, which helps decrease the difference between 1-G and 0-G enclosure comfort heights.

- The washing task can easily be accomplished with feet in a stationary fixed position, as would be the case with restraint shoes.

1.2.2.4 Maintainability Test

Scheduled maintenance of the potable water and waste water tanks were performed during the handwashing cycle tests. Also, unscheduled maintenance items were recorded which included a replaced check valve and the liquid level sensor (which was utilized from the preprototype unit).

1.2.2.4.1 Scheduled Maintenance

- Potable water tank was filled four times with the hand operated compression tank. A tedious operation, but it does charge-up the tanks to the desired level. Good access to quick-disconnect.

- Waste water tank drained four times without any problems. Good access to quick-disconnect.

- Soap tank did not require servicing during test after initial filling.

1.2.2.4.2 Unscheduled Maintenance

- A check valve was replaced on the waste water line, approximately a 10-minute operation.

- The liquid level sensor in the sump of the liquid-gas separator was replaced.

1.2.3 Hardware Modifications

The following hardware modifications were made to the Prototype Hand Cleansing Fixture as a result of testing.

1.2.3.1 Waste Water Check Valve Failure

After a few days water backed up into the sump of the liquid gas separator. Between the separator and the bladder tank is the water pump and check valve. The check valve was dismantled, cleaned and resinstalled. This check valve was used on the breadboard unit and contained contamination in the return spring preventing closure. After a series of runs, the valve again stuck open. The $1.37X10^4 N/M^2$ (2 psi) unit was replaced with a $6.89X10^4 N/m^2$ (10 psi) cracking pressure unit which has worked flawlessly. The stronger return spring has a quicker reaction time that prevents the high pressure fluid from surrounding the plunger in the check valve which can nullify its rapid sealing action.

1.2.3.2 LGS Level Sensor

The original liquid level sensor located in the sump of the liquid-gas separator consisted of a thermister and related electronics. As the water reached the thermister, the temperature change would be sensed as a change in current flow and would start the water pump. Once started, the pump would run for a pre-set time and then shut off. This system has marginal success, but erratic sensing at times did occur due to different water temperatures and sudsing. Toward the end of the cycle tests, the sensor became inoperative. Removing the sensor revealed excessive corrosion and deteriation. A new method of sensing water level was required, one that was insensitive to water temperature and corrosion resistant. The method used consisted of two stainless steel probes electrically powered which completes a circuit when water bridges the gap between the probes. All the electronics are kept the same as previously. Included in the electronics is an adjustable comparator component. This unit adjusts the sensitivity of the probe. For example, it can be adjusted to sense thin soap bubbles or highly mineralized water. A compromise setting that works well is one that will react to slightly aerated water.

1.2.3.3 Calibrated Soap Dispenser

The revised soap dispenser operated from a momentary switch. As long as the button was depressed, soap would be dispensed. Occassionally, a test subject would depress the button for an extended length of time resulting in excessive suds and waste of liquid soap. To eliminate this occurrence an electronic timer was added to the circuit that sets the open time of the soap dispenser such to dispense only 2cc (0.12 IN^3) of soap per activation.

1.2.3.4 Water/Soap Activation Button Size

The standard button on the water and soap activation switches was 0.006m (1/4 inch) in diameter. Some test subjects felt the button should be larger to eliminate the sharpness feel of the small button and to facilitate locating the button for operation. As a result a 0.0254m (one inch) diameter cap was installed over the standard button.

1.3 Conclusion of Test Results

A summary of the significant testing and resulting conclusions are listed in Tables 1-1 and 1-2. A more detailed description and discussion can be found in the breadboard and prototype test reports MCR-77-433 and MCR-78-600.

TABLE 1-1 CONCLUSION OF BREADBOARD TEST RESULTS

TEST	TEST OBJECTIVE	SIGNIFICANT DATA GENERATED	SIGNIFICANT CONCLUSIONS
Waste Chemical Disposal and Control of Evolved Gases	Use a charcoal filter to trap vapor from liquid chemicals.	o 12-83% efficient. o Possible fire or explosion with some chemical combinations. o Material compatibility problems with some chemicals.	Using the SUHCF as a chemical dump station is not recommended. A means of isolation and containment is required.
Microbial Burden and Disinfection Studies	Determine the magnitude of microbial burden on the interior surface of cleansing fixture.	o 460 percent increase at mid-day. o 768 percent increase at end of day. o Organisms die off if left standing a few days. o Soap tends to kill the micro-organisms.	Daily disinfecting is adequate and a disinfectant wipe could be used to clean and disinfect.
Neutral Buoyancy Test	Evaluate man/machine interfaces.	o Weightlessness body positions documented. o No fatique noticed in using fixture. o Test fixture height was comfortable to user. o Hand access holes were in a comfortable position.	Anticipated body positions were confirmed and height and configuration of the washing enclosure is adequate for the washing task in 1-G or 0-G.
SMD III Test	Examine the functional effectiveness of the breadboard unit in a "Real Life" lab situation.	o Foot switches were awkward to use. o Flaps on the hand access holes were undesireable. o Inside surface of enclosure should be smooth (no protrusions). o Soap dispensing system was inadequate. o No provisions for storing accessory items. o Cracks and crevices could support microorganism growth and would be difficult to clean.	Discrepancies were analyzed and corrective measures to be incorporated into prototype unit.
Zero Gravity KC-135 Test	To verify man/machine interface and functional performance during zero gravity simulation.	o LGS worked properly. o Water contained in enclosure during washing task. o Water spattered out during hand removal from enclosure. o No viewing problems with blower on. o Nozzle protrusion noticed. o Foot switches awkward to operate. o Shaving was messy. o Enclosure height ranged from 36-42 inches.	The basic concept performed well and refinements to the prototype will be made to eliminate problem areas.

TABLE 1-2 CONCLUSION OF PROTOTYPE TEST RESULTS

TEST	TEST OBJECTIVE	DATA GENERATED	CONCLUSION
Subsystem Checkout Test	Verify components meet designed performance.	o In the large bladder tanks 0.028m (7.4 gal) can be stored at 3.79×10^6 N/m^2 (55 PSIG). o Hot water temperature can be maintained at 313.7-324.8°K (105-115°F). o The soap tank will hold 0.003 m^3 (0.8 gal) at 3.45×10^5 N/m^2 (50 PSIG). o 0.5 cc of soap dispensed per activation. o Blower flow rate is 0.014 m^3/sec (30 CFM). o Pump works properly. o Timers adjusted on blower and water pump. o Total current draw is 6.2 amps on DC circuit and 1.25 amps on AC circuit.	All subsystems are working properly and unit is ready for cyclic task performance tests.
Task Performance Capability Test	Demonstrate the fixtures ability to perform the various cleansing tasks.	o 615 hand washings performed with an average of 154 per tank of potable water. o Water usage average was 0.18 Kg (0.4 lbs) per usage. o Elapsed time per washing cycle ranged from 30 to 130 seconds. o Soap usage averaged 1.85 cc per washing cycle. o Teeth brushing had limited success. Discharging into the enclosure was inefficient. o Shaving task was successful. o No difficulty in cleaning small utensils.	All cleansing functions can be satisfactorily accomplished with the prototype fixture.
Man/Machine Interfacing Test	Determine comfort range during operation by 5th percentile female through 95th percentile male.	o 40 different personnel of varying size used the prototype unit. o All extremes of personnel could easily reach the controls and comfortably operate the unit in both 1-G and O-G body positions.	All users adapted well to the fixture. The height and configuration of the enclosure and associated equipment has been optimized.
Maintainability Test	To document maintainability aspects of the prototype unit during cyclic tests.	o Filling tanks was a tedious task, but did charge tanks to desired level. o Water tanks serviced (4) times. o Soap tank serviced once. o Adequate accessibility to components for both scheduled and unscheduled maintenance.	The hand compression fill tank should be used only when other pressurized sources are not available. Component placement is adequate for performing maintenance tasks.

1.4 Problem Area Analysis

The only significant requirement that the washing fixture cannot comply with is that of being used for a chemical dump and storage. The one-gravity tests revealed this to be potentially dangerous and unreliable. Examination of the anticipated chemical waste list revealed the following problems:

- Radioactive materials may not be dispersed in a waste water system. They must be contained and isolated.

- According to the National Safety Council (October, 1975) the only way to eliminate hazards relating to the disposition of flammable solvents is strict adherence to the following procedure.

  > "Water-immiscible flammable liquids, or water miscible flammable liquids with flash points of less than 10°C (50°F) should never be disposed of in the laboratory drains or sewage system because of the hazards of fire or explosion."

- Many of the compounds discussed earlier rapidly attack plastics and rubber compounds causing undesirable chemical and physical changes. This characteristic means the fixture and all down-stream plumbing, valves, pumps, tanks, etc, must be resistant to virtually all solvents. Disposal of acids and bases in this system imposes a further restriction on choice of materials in that they must be corrosion resistant.

- Examination of the system schematic reveals further safety problems. Chemicals dumped into the fixture accumulate in the sump until pumped into the waste water tank. Violent reactions could take place in the sump as a result of indiscriminately dumping chemical waste into the fixture. Heat, high pressure, and/or toxic gases could be generated and could escape to the cabin air supply. Slower reactions could create similar problems downstream from the sump in plumbing or waste storage tanks.

- A brief examination of one-g methods for disposal of small quantities of complex, unknown, toxic, or carcinogenic compounds indicates these materials must first be detoxified by techniques specific for a particular type of compound. Frequently, these techniques use strong acids, strong bases and/or heat. Natrional Safety Council says

  > "A specific knowledge of the nature of the hazards (of this type compound) is required before they can be disposed of by any single method."

  The only realistic method for disposing of this category of chemical waste on the Shuttle/Spacelab is isolation and containment.

- o Many organic chemicals are capable of supporting microbial growth. Some problems this might cause in the hand cleansing system are: (1) buildup of pressure in lines and tanks from microbially released gases, (2) some of this gas taking up waste water storage area, (3) corrosion of metals, deterioration of rubber, etc. from microbial metabolites.

The hand cleansing fixture, as presently configured, should not be used to dispose of chemical waste materials. The main reason for this recommendation is the poor performance of the activated charcoal canister tested and the resulting safety problems discussed earlier.

The transfer of chemical waste to a container containing activated charcoal may be a solution for only certain types of waste because of material compatibility problems. The specific means of transferring the waste material in low-g would have to be developed and once the material was transferred, the original container would still have to be disposed of properly. In a simple static loading test (ethyl alcohol), vapor pressure created by dumping the alcohol over the charcoal was sufficient to cause the 16.5 gram stopper in a separatory funnel to bump for several minutes after dumping, indicating even with this method some material would probably escape to the cabin atmosphere.

It appears on the basis of this very cursory examination that the best solution to Shuttle/Spacelab chemical waste handling would probably be isolation and containment. A design of a simple rackmounted reagent storage container/box which has cooling, if necessary, and activated charcoal for absorption of stray vapors seems highly applicable. For each experiment they could then be placed back in the box and returned safely to earth for proper disposal.

1.5 Development Continuation Recommendations

1.5.1 Waste Chemical Fluid Disposal and Control of Evolved Gases

This area should be re-examined as an independant study to determine the latest probable types of waste chemicals that will be generated in Spacelabs. From this list a trade study should conducted to determine the optimum method of disposing these chemicals without endangering the safety of the crew and mission success for associated lab equipment.

1.5.2 Zero-Gravity Prototype Test

Since the prototype cleansing fixture has a different washing enclosure configuration and activation technique compared to the preprototype, it would be desirable to test the prototype in a zero-gravity environment. This test could be similar to the preprototype KC-135 test, with emphasis on water entrapment efficiency, visibility and man-machine interfacing.

1.5.3 Flight Hardware Development

The basic concepts used in the prototype unit have been demonstrated to perform the required cleansing functions needed to support biological operations on future life science spacelab payloads. The breadboard and prototype units identified the critical parameters and the optimum approach to comply with those requirements. A sufficient amount of data has been generated to confidently proceed to a flight unit development program.

2.0 TASK 1 RLSE REQUIREMENTS DEFINITION

This task defined the basic design criteria and requirements of the RLSE Space craft Utensil/Hand Cleansing Fixture for its integration with the zero gravity whole body shower hardware that makes up part of the RLSE program. These requirements and system identification are described in detail in document MCR-77-249 which was prepared during this task. The following paragraphs are excerps from that document and summarize the basic information developed during task-1.

2.1 Requirements

2.1.1 System Design Requirements

The RLSE Spacecraft Utensil/Handcleansing Fixture requirements are primarily established from the functions that the fixture must satisfy while maintaining the degree of safety necessary for a manned mission. Other contributing factors such as volume, comfort and privacy are associated with the vehicle interface with the fixture. The cleansing fixture must have the capability to operate in either a zero- or one-gravity environment. The gravity loads that the fixture must be designed to with-stand are three g's maximum for 1800 seconds (30 minutes) to satisfy launch and re-entry requirements and 12 g's maximum for crash loading.

From the projected 1980 (USAF population), anthropometric dimensions of a male and female and utilizing NASA Document JSC-09551, <u>Neutral Body Posture in Zero-G</u>, the fixture cabinet must be sized to accommodate both a 5th percentile female and 95th percentile male. The overall height and width of the cabinet must be such that it fits within a space lab rack maximum width 572 mm (22.52 in.).

2.1.1.1 Functional Requirements

The functions that the RLSE utensil/hand cleansing fixture must satisfy are to provide a crewman a means of handwashing, shaving, brushing teeth, body washing, and laboratory utensil cleansing while in a zero-gravity environment.

2.1.1.2 Performance Characteristics

2.1.1.2.1 Washing

- o Direct contact of water and cleanser on crewman's hands.
- o No loss of water into the habitability area.
- o Visual inspection of the cleaning operation by user.

2.1.1.2.2 Rinsing

- o Direct contact of rinse water.
- o No loss of rinse water into the habitability area.

2.1.1.2.3 Mode of operation

- o Manual, no time limitations on individual tasks.

2.1.1.2.4 System Purge

- o Fixture purges with air after each use.
- o Air filtered to remove contaminants and objectionable odors from chemical dumps.

2.1.1.2.5 Gas-Liquid Separation

- o Vortex separator incorporated in system.

2.1.1.2.6 Waste Fluid Stowage

- o System capable of storing various chemical waste fluids.

2.1.1.2.7 Power Usage

- o Peak load limited to 125 watts.

2.1.1.2.8 Soap/Cleansing Agent.

- o Pressurized Liquid Soap System.
- o Soap Dispersed upon demand.

2.1.1.2.9 Microbiological Control

- o Ion exchange resin bed in water supply line to prevent back contamination.
- o Periodic spraying of enclosure with disinfectant.

2.1.2 Subsystem Design Requirements

2.1.2.1 Water Supply and Distribution

This system shall provide ambient and heated water to the clansing enclosure. It shall consist of a 6.35 mm (1/4 inch) line system with fluid components to perform the above mentioned function. The potable ambient water delivered at the vehicle interface shall have a pressure requirement of 2.07×10^5 to 5.17×10^5 N/m^2 (30-75 psi) and a temperature requirement of $285.9-294.3^oK$ ($55-70^oF$). The water pressure required at the cleansing enclosure shall be 1.02×10^5 N/m^2 (15 psi) at a temperature of 320.4^oK (117^oF). The nozzle water flow rate shall be 11 ml/sec (.17 gpm). A Swagelok tube fitting shall be located at the spacecraft fluid interface.

2.1.2.2 Waste Collection and Processing

The purpose of the waste collection and processing system shall be to transfer water from the Liquid-Gas Separator (LGS) to the system-vehicle interface. The system shall consist of a 6.35 mm (1/4 inch) line system with fluid components. The waste water shall have a flow rate of $1.58 \times 10^{-5} m^3 sec$ (.25 gpm). The water pump shall consume power at a rate of 42 watts. A Swagelok tube fitting shall be located at the spacecraft fluid interface.

2.1.2.3 Air Processing

Means of moving water from the cleansing enclosure to the liquid gas separator (LGS) and delivering odor-free air back to the cabin environment shall be the purposes of the air processing system which shall be an open ended system. The blower shall have a flow rate of .007 m^3/sec (15 CFM) with a system pressure loss of 47 mm (1.85 inches) of water. The two-phase line from the enclosure outlet to the LGS shall be sized for a velocity greater than 1.22 m/sec (40 fps) to move the water from the enclosure to the LGS. The air outlet line shall have a flow rate of .0056 m^3/sec (12 CFM) with an inline charcoal filter to eliminate odor.

2.1.2.4 Soap Distribution

The soap distribution system shall provide liquid soap to the cleansing enclosure. It shall consist of a pressurized soap storage tank and a distribution system. The nitrogen gas needed to pressurize the system shall be tapped off the water pressurant system which is provided at the vehicle interface and shall be regulated to 1.72 x 10^5 N/m^2 (25 psi). The volume required of the soap storage bladder tank so that sufficient soap is available shall be 5000 cm^3 (.176 ft^3). The soap nozzle shall be sized to allow a flow rate of .5 ml/sec (.008 gpm).

2.1.2.5 Structural

The structural system shall support the cleansing enclosure and the electrical and fluid hardware. It shall be an aluminum angle type structure with brackets and panels. The design loading shall be 3 g's maximum for 1800 sec (30 min) to satisfy launch and reentry requirements and 12 g's maximum for crash loading. The unit shall be designed to be installed into a Spacelab Standard rack attached to the floor structure.

2.1.2.6 Electrical Power and Control

The electrical system shall provide electrical power to the components and controls. Two power sources shall be utilized--a 28 vdc which has a maximum load of 150 watts and a 115 vac, 1/, 400 Hz which has a maximum load of 115 watts.

The control system shall provide sufficient control of cleansing variables resulting in a convenient and comfortable cleansing. The controls shall consist of a central control panel plus remotely operated switches. The remote switches shall be a means of manual control (on-off) of the water and soap distribution. The control panel shall consist of a main power switch, heater on-off switch, a blower on-off switch, a water pump mode selector (auto-off-manual), and a disinfectant on-off switch.

2.1.2.7 Man-Machine

The man-machine interface requirements shall assure that the human engineering criteria for zero-gravity tasks are complied with. To achieve this then, the control panel shall be within easy reach and sight of each crewman, the cleansing enclosure shall be positioned for optimum comfort in zero-gravity and the equipment requiring maintenance shall be located for ease of access.

2.1.2.8 Microbiological Control

The microbiological control system purpose shall be to control the microorganisms within the cleansing fixture. The system shall consist of a gas pressurized disinfectant storage tank and a distribution system. Nitrogen gas, required to ressurize the system, shall be delivered at the vehicle interface and shall be regulated to 1.72×10^5 N/m^2 (25 psi). The disinfectant storage tank shall have a volume of 3785 cm^3 (.13 ft^3) to store the required amount of disinfectant needed for a 30-day mission. The disinfectant flow rate shall be 22.7 ml/sec (.36 gpm) from three nozzles within the cleansing enclosure.

2.1.2.9 Pressurant

This system shall provide nitrogen gas at a desired pressure to the soap, disinfectant, waste water and supply water bladder tanks. The system shall consist of a 6.35 mm (1/4 inch) line with required components to achieve this task. The nitrogen gas incoming to the vehicle system interface shall have a pressure of 2.1×10^5 N/m^2 (30-100 psi). The nitrogen gas pressure at the bladder tanks shall be regulated to 1.72×10^5 N/m^2 (25 psi).

2.1.2.10 Waste Chemical Fluid Disposal and Control of Evolved Gases

Spacelab chemical waste handling shall be through isolation and containment. A rack-mounted reagent storage container/box which has cooling, if necessary, and activated charcoal for absorption of stray vapors shall be utilized in storing any waste chemicals which may result from the laboratory experiments. After the experiment, the chemical waste shall be placed in the box and returned safely to earth for proper disposal.

2.1.3 Materials, Parts and Processes

See section 3.3 in MCR-77-249 for a description of the requirements for materials, parts and processes normally used for flight articles. The RLSE unit represents the flight unit in terms of configuration, equipment layout and component performance, but not necessarily in the area of spacecraft material compatibility.

2.1.4 Interface Design Requirements

2.1.4.1 Electrical

A 115 vac, single phase, 400 cycle power source (150 watt peak load) and a 28 vdc power source (175 watt peak load) shall be provided at the vehicle interface for the electrical components. The interface will be located at the back surface of the rack and mating connectors will be provided.

2.1.4.2 Fluid

Potable water shall be provided at the vehicle interface at a pressure of 2.07×10^5 - 5.17×10^5 N/m^2 (30-75 psi) and at a temperature of 285.9 - 294.3°K (55-70°F). The interface will be located at the back surface of the rack and Swagelok fittings will be used.

2.1.4.3 Structural

The structure of the utensil/hand cleansing fixture shall be such that it fits into a Spacelab standard rack and is mounted adjacent to the SSP shower assembly.

2.1.4.4 Environment

The utensil/hand cleansing fixture shall operate in the cabin ambient environment where the temperature ranges from 291°K (64°F) to 300.4°K (81°F) dB and the humidity will be controlled between 25% and 70% (not adjustable). Latent and sensible heat impacts for various operating conditions are described in paragraph 3.5.3 in MCR-77-249. The cleansing fixture shall also be capable of operating in either a one-g or zero-g environment.

2.1.4.5 Waste Water/Air Drain

An interface for the drain line on the handwasher shall be located at the back surface of the rack and shall consist of a 38.1 mm (1.5 inch) diameter tube.

2.1.4.6 Man

The man-machine interface involves the positioning of the enclosure and controls for comfortable access for a 95th percentile male and 5th percentile female. Figure 2-1 and Figure 2-2 describe the natural zero-gravity position and provides the anthropometric data for the male and female.

2.1.5 Allocation of Peformance Budget

MCR-77-249 described and listed the predicted water usage and balance; power requirements for the blower, solenoids, water pump and water heater; environmental impact of latent heat and sensible heat; estimated weight including equivalent weight penalties for sensible heat, DC power and AC power consumption.

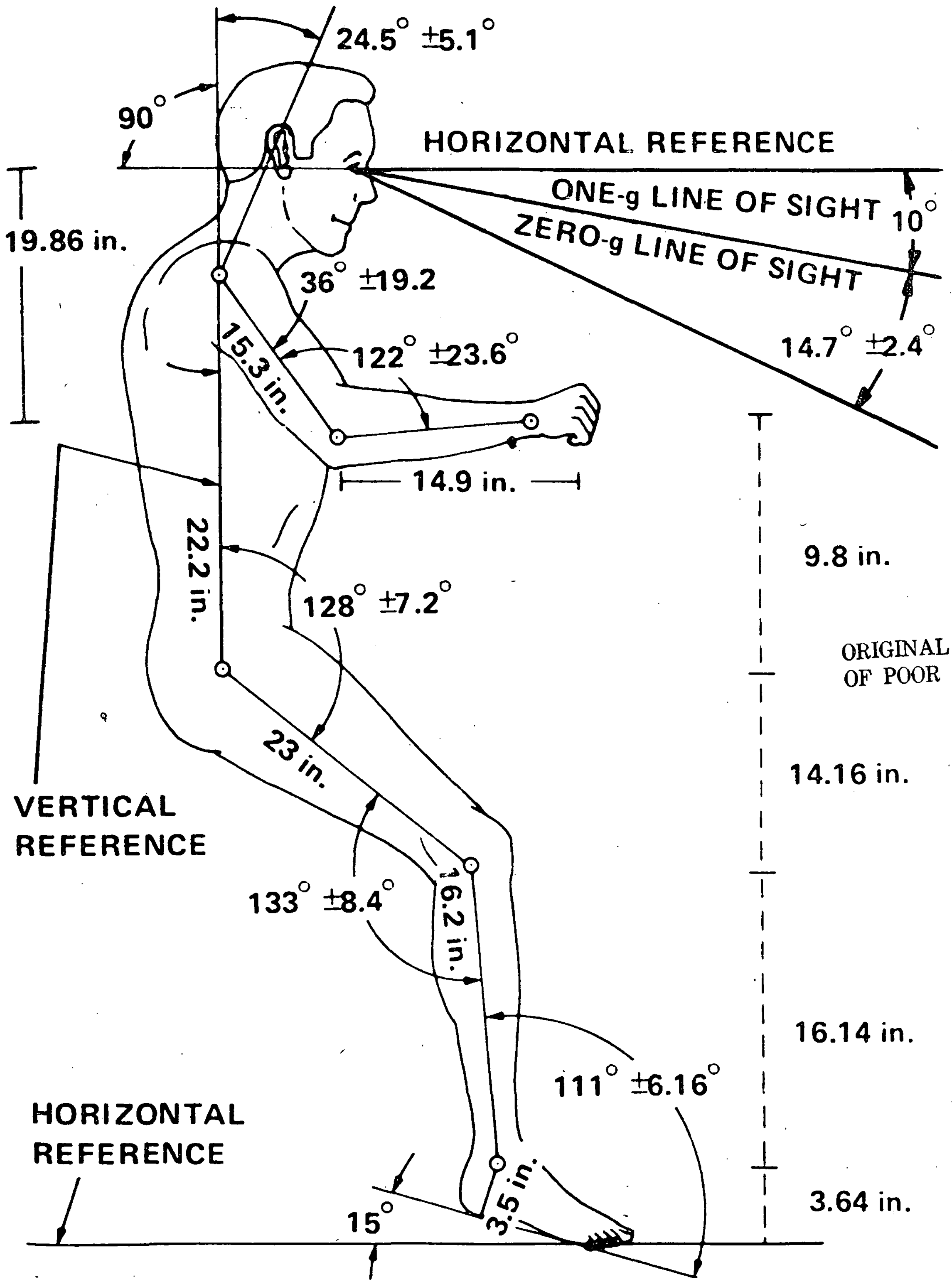

FIGURE 2-1 ANTHROPOMETRIC DIMENSIONS OF A 95TH PERCENTILE MALE

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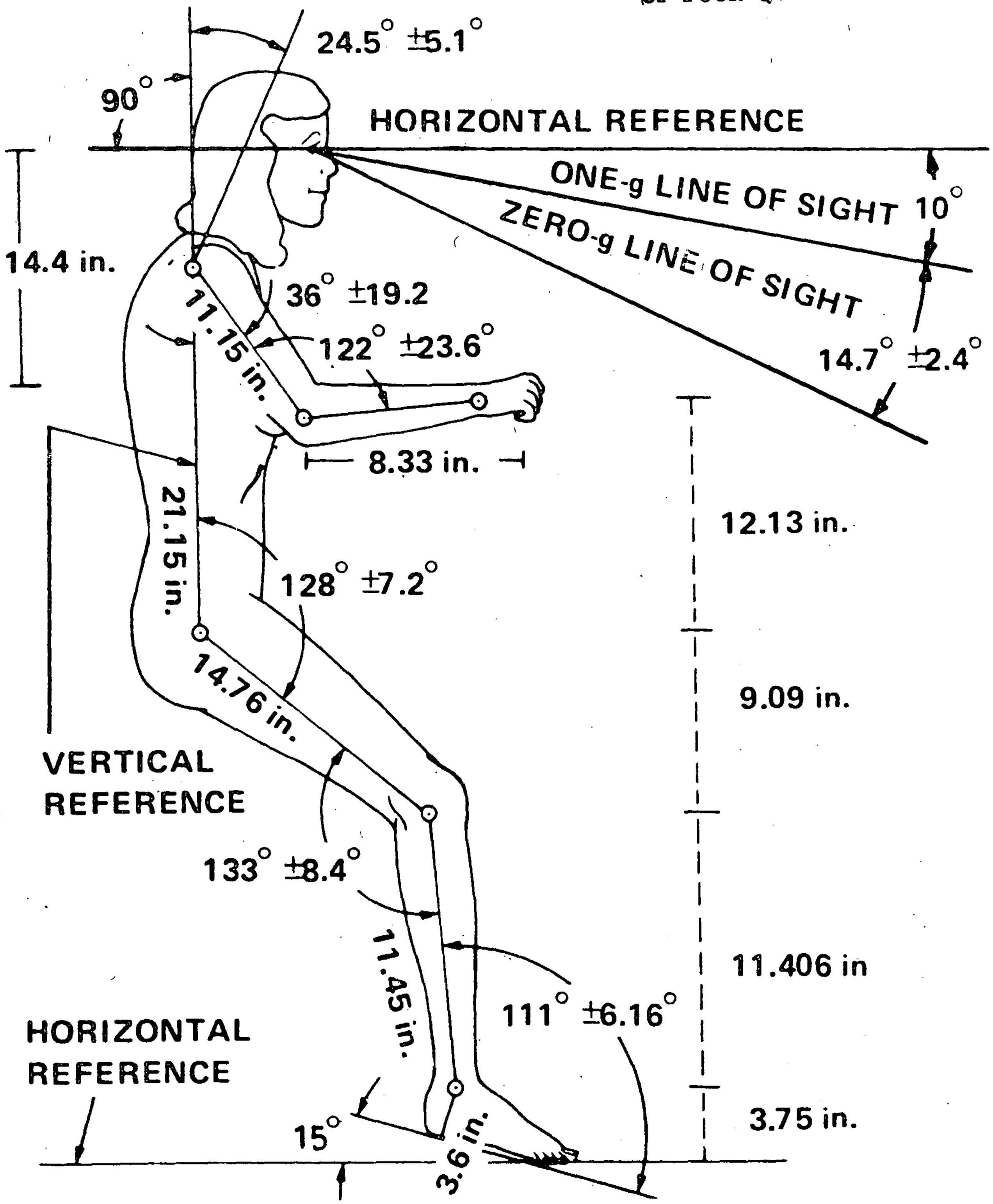

FIGURE 2-2 ANTHROPOMETRIC DIMENSIONS OF A 5TH PERCENTILE FEMALE

2.2 Preliminary System Design

Refer to section 5.0 in this report for the latest system description.

2.3 Maintenance

The Requirements Definition Document MCR-77-249 included a section on maintenance where results of a FMEA study are discussed.

The completion of the requirements definition lead into the next task, breadboard design and fabrication.

3.0 TASK-2 BREADBOARD DESIGN AND FABRICATION

3.1 Breadboard Design

The cleansing fixture breadboard hardware consisted of subsystem components mounted on a 6061-T6 aluminum structural assembly. The mechanical and electrical schematics of the breadboard system are shown in Figures 3-1 and 3-2 respectively. The major subsystems included the following:

- Water Supply and Distribution
- Enclsoure
- Waste Collection and Processing
- Air Processing
- Soap Distribution
- Pressurization
- Electrical Control
- Structural Support

The installation of these subsystems are shown in Figure 3-3. A brief description of the major subsystems are included as follows:

3.1.1 Water Supply and Distribution

The purpose of this subsystem was to provide heated water to the cleansing enclosure. Water was stored in a $4.54 \times 10^{-3} m^3$ (1.0 gallon) bladder tank. The tank was wrapped with a flexible drum heater that was controlled with an external thermostat. The heater was rated at 650 watts and controlled the water temperature to 319^oK (115^oF). A 3-way valve allowed filling the tank. The pressure behind the bladder forced water to the nozzle when the solenoid shutoff valve was opened. The nozzle was located inside the enclosure and was adjustable from a full cone spray $1.8 \times 10^{-5} m^3/sec$ (0.24 GPM) to a straight stream $5.8 \times 10^{-5} m^3/sec$ (0.78 GPM).

3.1.2 Enclosure

The enclosure consists of an upper 27.94 centimeter (11 inch) clear plastic dome and a lower stainless steel cone portion mounted on an adjustable 6061-T6 aluminum structure. The adjustable structure is shown in Figure 3-4 and is mounted to the unit basic support structure. This allowed for vertical height adjustment of up to .15m (6 inches) during testing. The upper dome had two 7.62 centimeter (3 inches) diameter hand access holes located 90^o apart and covered with slitted butyl rubber for water splash retainment. The dome was hinged and could be lifted upward to 90^o by unlocking 4 latches (see Figure 3-5). The stainless steel base, shown in Figure 3-6, contained a removable strainer.

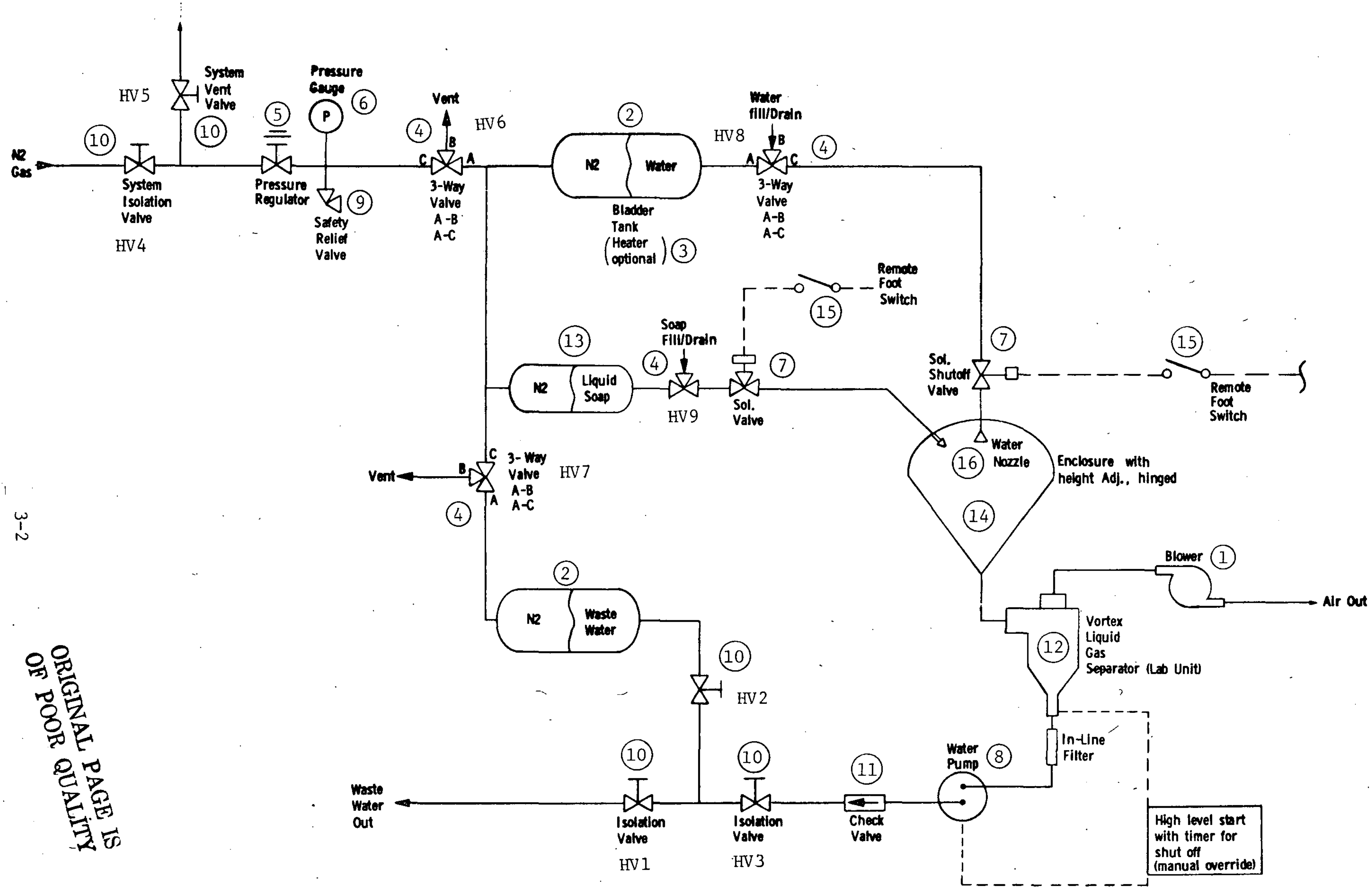

FIGURE 3-1 CLEANSING FIXTURE BREADBOARD DESIGN MECHANICAL SCHEMATIC